CANMET

Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

Metals Technology Laboratories

Laboratoires de la technologie des métaux

Energy, Mines and Resources Canada

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PHASE II

PROPOSED TECHNICAL WORK SCOPE

CANMET/Industry ECA Initiative
Phase II

Engineering Critical Assessment of
Hydrogen-Charged
Service-Damaged Pressure Vessels

Project 702602325
April 1992
NJS/RFO

MICROMEDIA

22 pp

1.0 Introduction

This proposal outlines a work statement for Phase II of the CANMET/Industry ECA Initiative on the engineering critical assessment (ECA) of service-damaged pressure vessels. It was developed under the auspices of an Ad-hoc subcommittee consisting of the following representatives: N. Smith (CANMET/MTL); R. Orr (CANMET/MTL); T. Lau and O. Lepik (Ontario Hydro); E. Sperling (Amoco); R. MacDonald (Mobil Oil); P. Teevens (Amerada Hess); and K. Gottselig (Syncrude Canada).

The objective of this Phase II protocol is to examine two condemned pressure vessels where flaws are the result of environmental cracking in wet hydrogen sulfide. To that end, engineering critical assessments will be conducted on these vessels to determine their fitness-for-service with respect to similarly flawed in-service units that may currently be operating in sour service. Crucial to the success of the project is the determination of:

1) the material properties in the hydrogen-charged condition;
2) the extent of damage by various non-destructive examination methods (flaw sizing);
3) the predicted failure pressure and mode by fracture mechanics;
4) the measurement of actual crack (flaw) propagation rates; and
5) the failure conditions to confirm the predicted failure pressure and mode by means of a burst test.

1.1 Background

A co-operative program between the Metals Technology Laboratories of CANMET and several representative organizations from the petroleum, gas transmission, and electrical utility industries was initiated with the aim of promoting the acceptance of an engineering critical assessment (ECA) methodology for service-damaged pressure vessels in process plant equipment by the various code and regulatory bodies. The long-term goal is to develop relevant clauses for incorporation into CSA Standard B51 - Boiler, Pressure Vessel and Pressure Piping Code.

Engineering critical assessment is a means for deciding the necessity and timing of a vessel repair or replacement. ECA procedures, which are based on fracture mechanics, can be used to assess the risk of operation of a damaged vessel by predicting the amount of damage that can be tolerated before failure, and thus determine the need for repair or replacement. Valid ECA procedures would allow owners and insurance underwriters of pressure vessels and the governing regulatory authorities to assess the integrity of the vessel, avoiding costly and unnecessary repairs, and ensuring that the probability of failure during service remains acceptably low, thereby increasing the safety of workers, the public, and the environment.

There are many moderately thick as-welded pressure vessels in process plants that are subject to hydrogen-charging environments, such as wet hydrogen sulfide service. Operating experience has shown that the heat-affected zone of welds in these vessels may be sufficiently

hard that they are susceptible to sulfide stress cracking. However, even though these cracks can quickly encounter the tougher base material and stop growing, the current approach, as required by all the codes in regular use, is to repair any detected crack, no matter how small. Unfortunately, the heat affected zones of repair welds are again subjected to the same type of cracking as before and thus the cycle of inspection and repair continues. All codes in regular use for process plant equipment state that detected crack-like flaws are unacceptable, irrespective of size, and must be repaired or the vessel replaced.

In contrast, the engineering critical assessment approach shows that small cracks, especially once their tips have emerged into base material from the heat affected zone, can be safely left in place. If such a conclusion can be arrived at with a high degree of confidence, then it would not only lead to considerable cost savings but also a safer structure since poorly executed repair welds are often the cause of vessel failures.

The first phase of a three-year CANMET/Industry co-operative program was therefore launched in 1988 to validate an ECA approach for a pressure vessel containing damage induced by sour service. A key component of this Phase I program was a hydrostatic burst test in 1990. The pressure vessel, a knock-out drum fabricated to ASME Section VIII - Division 1 using SA 516 Gr 70 steel, was selected as a typical example of the plain carbon/ manganese steel pressure vessels currently being used in North American process plants. Cracking was detected at several weld locations after ten years of wet hydrogen sulfide service. The cracking was so extensive that the vessel was subsequently withdrawn from service. The approach followed in this program was to inspect the vessel to establish the flaw sizes using a variety of techniques and then use ECA methodology to predict the vessel's failure pressure during the controlled hydrostatic burst test. Metallographic and fractographic analyses were done after the burst test to establish the actual flaw sizes and review the ECA predictions. As a result of these analyses, it was concluded that both the simple preliminary analysis and the more detailed ECA approaches successfully provided conservative predictions of the failure pressure. The failure pressure was approximately five times the design operating pressure although the vessel had several flaws which had caused it to be condemned. It was also evident that several flaws were associated with repair welds suggesting that repair of minor cracks which ECA may prove to be harmless may instead lead to more severe cracking.

Phase I of the CANMET/Industry ECA program showed that the continued safety of in-service pressure vessels can be conservatively estimated with limited information on material properties using existing ECA techniques. However, the burst test in Phase I of the project did not simulate in-service conditions because the vessel wall was not charged with hydrogen. The presence of hydrogen in steel can significantly reduce the fracture toughness. Ontario Hydro Research (Ref 1) reported that at 21 degrees C, hydrogen-charged A516 Gr 70 specimens had only one-third the J-resistance curve toughness compared to nominally identical uncharged specimens. Exxon Research (Ref 2) reported that hydrogen-charged A516 Gr 70 specimens had CTOD toughness reductions down to one-fifth compared to the uncharged condition. A reduction in vessel steel toughness of these magnitudes may cause the failure to change from a plastic collapse mode, as observed the Phase I project, to a fracture-dominated mode, associated with small vessel strains.

1.2 Proposed Project

To confirm the industrial applicability of current ECA approaches for service-damaged pressure vessels where the flaws are the result of environmental cracking in wet hydrogen sulfide, engineering critical assessments of two condemned service-damaged pressure vessels will be carried out. Burst tests to failure will be conducted on these vessels to confirm the validity of the assessments. These burst tests will be conducted using a hydrogen-charging environment so as to simulate actual service conditions:

1) The first burst test will be carried out on a vessel that contains a relatively deep "designer" flaw, approximately half the thickness of the shell, to achieve a fracture-dominated failure so as to simulate a realistic failure (near actual operating pressure).

2) Another burst test will be carried out on a vessel that contains actual service flaws. This will be done to confirm that current ECA methods can predict the continued safety of damaged vessels, with small flaws, that are subject to a hydrogen-charging environment. A second objective of this burst test is to advance the long-term goal of influencing the code and regulatory authorities.

2.0 Approach

The proposed Phase II of the ECA program will be established as a group-sponsored collaborative project similar to the recently completed Phase I. It is proposed that the total cost of the project will be shared by the participants, including CANMET, in the following manner:

1) In-kind Contributions. It is proposed that a significant portion of the work will be done by the participants of the project. The non-destructive examination, the ECA and the post-burst-test analysis will be carried out as a series of round-robin exercises, on a voluntary basis. The intention is both to reduce the out-of-pocket costs to the participants of the project and to show the industrial applicability of ECA techniques.

2) Direct Cash Contribution. Direct cash contributions, matched by CANMET, will be required to cover the contractual costs incurred by the project. These additional costs are associated with conducting the burst tests, including some non-destructive inspection and the measurement of material properties and are estimated to be $400,000. CANMET will absorb up to 50% of these additional costs ($200,000), the remaining costs being shared equally by the participating sponsors. The project is considered feasible if a minimum of ten participating sponsors commit to the project. With ten sponsors, the cost for each sponsor will be a maximum of $20,000. In Phase I, there were fourteen participating sponsors. Based on expressions of interest from potential sponsors, it is anticipated that at least fifteen sponsors will commit to the project. A minimum commitment of $10,000 will be required if the number of sponsors exceeds twenty. The scope of work will be adjusted to the resources available.

A Technical Steering Committee will be formed consisting of one member of each sponsor and one member from CANMET. All technical decisions on the scope of work, appropriate methodology, etc. will be made by this Technical Steering Committee. It is anticipated that subcommittees will be formed during the project to address specific technical elements. These subcommittees will be chaired by members of the Technical Steering Committee. Technical Steering Committee members will be empowered to nominate another member of their company for the subcommittees so as to obtain pertinent technical expertise for the program.

The Metals Technology Laboratories (MTL) of CANMET will assume the overall project administration under the direction of the Technical Steering Committee and act as the Referee Lab for the round-robin exercise. R. Orr of CANMET/MTL will act as the project manager to administer the sub-contracts and to chair the Technical Steering Committee meetings. Meetings of the Technical Steering Committee will be organized as required.

Deliverables will consist of:

1) Monthly Progress Reports in letter format. If there has been no significant activity, no report will be issued.

2) Subcontractor Reports, issued at the completion of tasks by the subcontractors, as part of the contractual requirements.

3) Final Report. Since the purpose of this program is to influence the Regulatory Authorities and the CSA committees, it is intended that the Final Report of this project will be placed in the public domain at the completion of the project. The Final Report will be a summary document of the project results and will not identify sub-contractors or round-robin participants.

In addition, the data reports from the major tasks, including the results of the non-destructive examination, the fracture mechanics predictions, and the post-burst test analyses, will be circulated to the participants of the project as they become available.

3.0 Experimental Program

3.1 ECA of First Vessel

An engineering critical assessment will be carried out on a vessel containing a deep flaw and confirmed with a burst test. This deep flaw will be approximately half the thickness of the shell, so as to better simulate a realistic failure mode (near the operating pressure of the vessel) by a fracture-dominated failure.

Cracking of pressure vessel components in environments containing wet hydrogen sulfide is most likely to be of a slow, time dependent nature and failure will occur when the flaw attains a critical size. To simulate an actual service failure, the burst test must:

1) characterize cracking under normal vessel operating conditions, and

2) ensure that a fracture-dominated failure occurs.

To ensure a fracture-dominated failure, that is a failure at small vessel strains, it is felt by the Ad-hoc subcommittee that the test vessel should contain a large surface flaw ($0.5 < a/t < 0.7$). Since a candidate vessel containing a flaw of this depth is not available, the Ad-hoc subcommittee recommends that a window or patch be placed in the test vessel. This window would have a single "designer" flaw with a depth of half the shell thickness vessel. The test vessel would then be, in effect, a "soft" biaxial loading system for the "designer" flaw.

This designer flaw could be an actual (shallower) service-induced flaw that is removed from the vessel shell and grown by placing in a NACE TM-01-77 or similar solution. Alternatively, the designer flaw can be induced at a weld heat-affected zone by using a suitable welding electrode and grown in the same manner.

Besides simulating a realistic failure mode, further benefits of this approach include:

1) the growth of the flaw can be monitored, since the location of the critical flaw will be known;

2) the use of acoustic emission can be properly assessed;

3) leak before break can be investigated/demonstrated.

3.1.1 Candidate Vessel No. 1

Candidate vessel No. 1 has been made available to the project, courtesy of Poco Petroleum. This vessel was a glycol separator and was fabricated in 1969 to ASME Section VIII - Division I 1968 rules using SA 516 Gr 70 steel for the shell and heads. It is 6.71 m in overall length and 1.23 m internal diameter, with a nominal wall thickness of 25.4 mm. According to the specifications, after fabrication this vessel was fully radiographed and was post-weld heat-treated in accordance with the ASME code.

Figure 1 illustrates all the welded seams and major nozzle locations. It also shows the position of the internal attachments including a splitter plate at the inlet nozzle.

The vessel was in sour service at an operating temperature of -20^0 C and an operating pressure of 3300 kPa. The vessel was recently withdrawn from service because of extensive cracking and blistering. The cracking is generally associated with the heat-affected zone of the internal welds. A summary of the inspection report is attached.

The shell of this vessel is fabricated from three cans, each approximately 1.9 m long. It is proposed that one head and one can be removed from the vessel and the head rewelded on the remaining two cans to make a purpose-built test vessel. The material from the removed can will be used to make a patch containing the designer flaw. An additional sample will be cut from this can for the measurement of the material properties.

3.1.2 Non-Destructive Examination

A non-destructive examination of the vessel will be made to establish the length and depth of the existing flaws and to identify a possible "designer" flaw. This examination will consist of wet fluorescent magnetic particle and ultrasonic inspection, using standard industrial practice.

3.1.3 ECA

Predictions of the failure pressure and mode will be done by the participants in a round-robin exercise. These predictions will focus on the "designer" flaw, with limited analyses done on the existing service flaws.

3.1.4 Measurements of Mechanical Properties

For conducting an engineering critical assessment, the actual material properties, as influenced by the presence of hydrogen, will be measured.

To measure the toughness and tensile properties of the weld metal, the heat-affected zone, and the base material, a sample of the pressure vessel shell, containing both base material and weld seams, will be removed from the vessel. The location of this sample will be selected by the Technical Steering Committee.

Pre-cracked rectangular (Bx2B) fracture mechanics specimens will be produced from the sample. The machined specimens will be charged with hydrogen either electrolytically with a conventional cathodic poison, or by corrosion in a hydrogen sulfide environment. A range of charging conditions and environments may be employed. The charging time shall be sufficient for equilibrium hydrogen concentration to be attained throughout the specimen. The hydrogen concentration will be measured on blanks following charging and on broken specimens after toughness testing. Following charging, the specimens will be stored at low temperature until toughness testing is carried out.

Toughness testing will be done at a strain rate that is sufficiently low to observe embrittlement without making the test duration too long. This strain rate will be determined by an initial series of tests. Exxon (Ref. 2) used a cross-head displacement rate of 0.008 mm/minute on hydrogen-charged three point bend specimens.

The testing of the specimens will be done at CANMET, as part of an in-house program at MTL that is already underway. Other participants may wish to do corroborative work as part of the collaborative effort. The machining and preparation of the mechanical test specimens will be contracted and is estimated to cost $ 40,000.

3.1.5 Burst Test

The predictions of the failure pressure will be confirmed by a burst test of the vessel using a hydrogen-charging environment.

To simulate actual service conditions, the pressurization during the burst test should be slow, consisting of hold periods typically of two to six hours duration. This will allow time for the hydrogen to diffuse to the crack tip region. Guidance on the appropriate strain rate is expected to be obtained from the measurement of the material's properties. The initial pressure will be selected to give a stress in the vessel shell which is equivalent to a lower bound K_{Ic} for SA 516 Gr. 70 steels.

The burst test will be monitored with strain gages. hydrogen flux probes, acoustic emission, and possibly potential drop probes. Based on the experience with acoustic emission in Phase I, the number of probes will be limited so as to focus on the flaw of interest. A maximum budget of $20,000 has been allowed for monitoring the burst test.

For the burst test, the hydrogen-charging of the vessel wall can be accomplished by using either:

1) a hydrogen sulfide solution (such as NACE TM-01-77);

2) or by cathodically charging the vessel, using a suitable anode (platinum or stainless steel), and a solution such as a mild sulfuric acid solution with an arsenic recombination inhibitor.

The method preferred by the Ad-hoc subcommittee is to use the hydrogen sulfide solution, since it is felt that this most closely simulates actual service conditions and duplicates the actual crack growth mechanism. However, there may be an additional cost associated with this method and there are additional safety and environmental concerns that must be addressed. The choice of technique will be made by the Technical Steering Committee, subject to the approval of the Federal Environmental Assessment Review Panel (EARP).

A suitable location must be selected for the burst test. Two possible locations are the Defence Research Establishment Suffield (DRES) in southern Alberta and CFER in Edmonton. DRES has expertise in conducting experiments with toxic or hazardous substances. A burst test at Suffield would be conducted outside. There is a bunker available for personnel and equipment. CFER has a special environments facility in Edmonton that is suitable for the burst test. This facility consists of twin in-ground test chambers providing secondary containment for toxic and flammable gases with the capacity to contain explosions and enable the safe simulation of corrosive and flammable environments. Each sealed test chamber is 9.5 m long and 2.4 m diameter, and will hold the candidate vessel (with the manway nozzle projection or boot removed).

DRES is the location preferred by the Ad-hoc subcommittee, based on preliminary costs and the outside location; however, the final selection will be decided by the Technical Steering Committee, subject to approval by EARP.

3.1.6 Post-Burst Test Analyses

The primary objective of this task is to measure the "designer" flaw by fractographic methods and to compare its actual dimensions with the respective values measured by the non-destructive inspection.

3.2 ECA of Second Vessel

An engineering critical assessment will be carried out on a second vessel that contains actual service flaws and confirmed with a burst test. This will be done to confirm that current ECA methods can predict the continued safety of damaged vessels with small flaws that are the result of environmental cracking such as wet hydrogen sulfide. A second objective of this burst test is to advance the long-term goal of influencing the code and regulatory authorities.

3.2.1 Candidate Vessel No. 2

Candidate vessel No. 2 has been made available to the project, courtesy of Poco Petroleum. This vessel was screened from several candidate vessels and was selected by the Ad-hoc subcommittee based on the nature of the flaws within the vessel.

The candidate vessel was a glycol separator and was fabricated in 1973 to ASME Section VIII - Division I 1971 and CSA B51 (1972) rules using SA 516 Gr 70 steel for the shell and heads. The vessel is considered as representative of vessels in sour service. It is 5.72 m in overall length and 1.52 m internal diameter, with a measured wall thickness of 33.5 mm. According to the specifications, this vessel was fully radiographed and was post-weld heat-treated after fabrication in accordance with the ASME code.

Figure 2 illustrates all the welded seams and major nozzle locations. It also shows the position of the internal attachments including two demister support rings and a splitter plate at the inlet nozzle.

The vessel was placed in sour service in Alberta at an operating temperature of -20^0 C and an operating pressure of 3500 kPa. The vessel was recently withdrawn from service because of extensive cracking and blistering. The cracking is generally associated with the heat-affected zone of the internal welds. A summary of the inspection report is attached.

3.2.2 Non-Destructive Examination

Non-destructive examination (NDE) will be performed on the pressure vessel. The NDE will be carried out following typical industry practice to establish the flaw depths and lengths for the ECA predictions. A further objective is to show the viability of current industry practice to provide acceptable data for ECA.

Wet fluorescent magnetic particle inspection and manual ultrasonic inspection will be

carried out by a contractor using standard industrial practice to provide a reference inspection for the project. The manual ultrasonic inspection will be carried out by teams from various project participants in a co-operative round-robin effort. The focus will be on manual ultrasonic techniques that have industrial relevance, but it is hoped that some participants will use advanced techniques such as manual time-of-flight diffraction. Mechanized ultrasonic inspection techniques will be used if the flaws are located in a position that is suitable for inspection and if these techniques can be contracted at a cost of less than $20,000.

3.2.3 ECA

An engineering critical assessment will be done to predict the failure mode and pressure. ECA analyses will be carried out by various project participants in a co-operative round-robin effort. The focus will be on preliminary analyses, using handbook values of material toughness. For comparison, more detailed analyses will be done with measured values of material toughness. A maximum budget of $20,000 is allowed for any contracted finite-element calculations. The post-burst test analyses, using actual flaw depths, will be done by the participants in a round-robin exercise.

3.2.4 Burst Test

This second burst test will be conducted immediately after the first test. The vessel will charged with hydrogen in a similar manner to the first test.

3.2.5 Post-Test Analyses

The sizes of the principal flaws will be measured by fractographic means and compared to the dimensions established by the non-destructive inspection. The nature of the flaws in relation to their initiation and growth will also be established. It is anticipated that this will be done by the participants as a round-robin exercise. The selection of the flaws to be investigated will be made by the Technical Steering Committee.

4.0 Project Cost Estimates

The total additional funds required to cover the out-of-pocket expenses for the proposed project is estimated to be $400,000. The Crown's share of this will be a maximum of 50% or $200,000. As defined in the proposed approach, many of the tasks to be performed can only be estimated at this stage. Additionally, the selection of subcontractors will depend on the Technical Steering Committee, in conjunction with Supply and Services Canada. The project manager will be soliciting update bids as the project moves through its various stages.

4.1 Estimated Project Contractual Costs

Preliminary (CANMET/Subcontractors)	
- trucking of vessels	$ 12,000
- vessel storage (at fabricator)	15,000
- sandblasting	15,000
NDE Inspection (subcontractors)	
- Wet fluorescent magnetic particle	5,000
- manual UT	12,000
- mechanized UT	20,000
ECA (Subcontractors)	
- preliminary analysis	10,000
- detailed analysis	20,000
- post-burst-test analysis	10,000
Material Property Measurements (CANMET/Subcontractors)	
- specimen machining and prep.	40,000
- patch extraction and repair	20,000
Designer flaw preparation (CANMET)	18,000
Preparation of vessel for burst test (subcontractors)	
- sealing nozzles etc	40,000
- engineering	20,000
Burst tests (CANMET/subcontractors)	
- tests	80,000
- acoustic emission monitoring	6,500
- monitoring burst test	15,000
Post burst test analysis (round robin)	5,000
Subtotal	343,000
Project Management (15%)	51,500
TOTAL	$ 395,000

4.2 Time Frame

Based on the foregoing, the proposed schedule for the project is a start date of September, 1992, with completion by September 1994. In order to met this timeframe, the burst tests must be conducted in the late summer of 1993, subject to the availability of the test site.

5.0 References

1. Lepik, O.E.; Carpenter, D.W. 1989. Fracture Properties of Bruce Heavy Water Plant Hydrogen-Blistered A516 Gr 70 Carbon Steel. Ontario Hydro Research Division report no. 89-135-K.

2. Humphries, M.J.; McLaughlin, J.E.; Pargeter, R. 1989. Toughness Characteristics of Hydrogen-Charged Pressure Vessel Steels. Proc. Int'l Conf. Interaction of Steels with Hydrogen in Petroleum Industry Service March 28-30 Paris France :243-248.

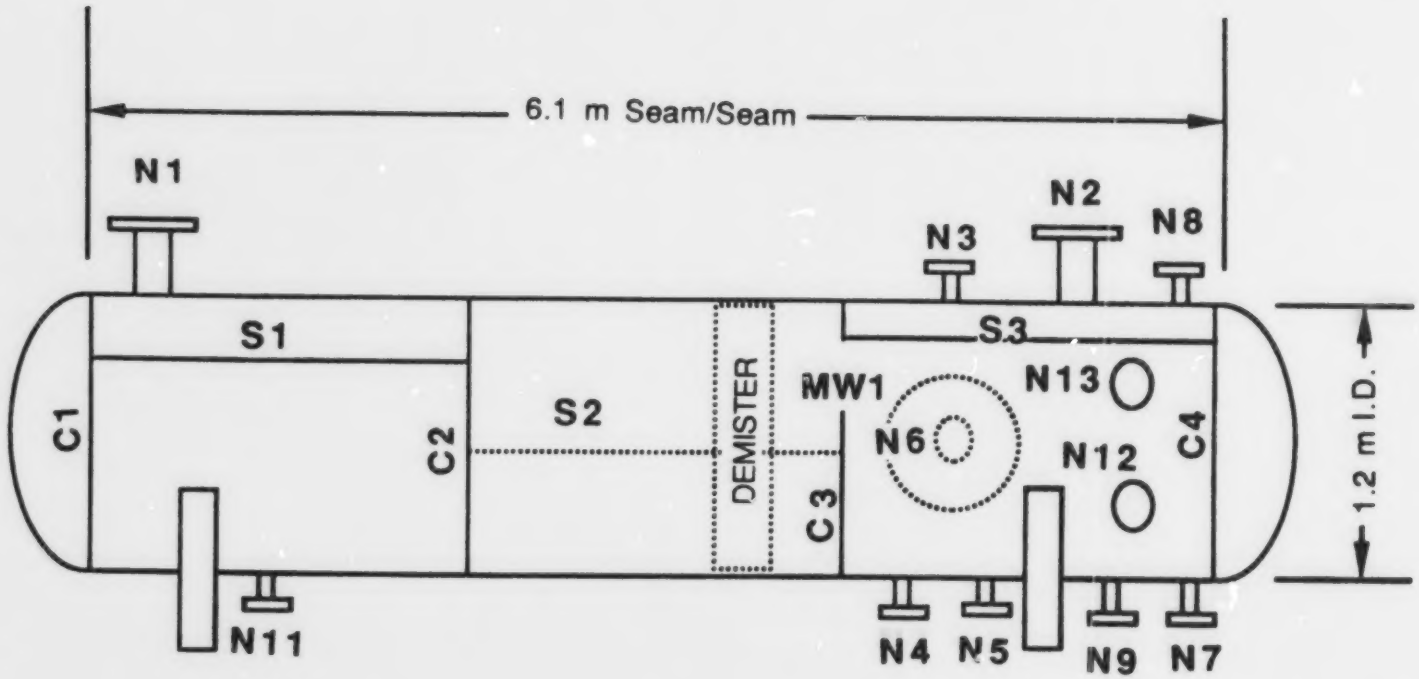

Figure 1 **No. 1 Train, Sour Glycol Separator**

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MATERIALS ENGINEERING AND TESTING

1989 SHUTDOWN INSPECTION REPORT

SOUTH STURGEON LAKE GAS PLANT

Date: April 1990
Pages: 1 of 2
No. of Drawings: 1

IDENTIFICATION: PV-17.05; A-82506

EQUIPMENT DESCRIPTION: No. 1 Train, Sour Glycol Separator

TYPE OF INSPECTION: Internal Wet Fluorescent Magnetic Particle
Ultrasonic Flaw Detection

AREAS INSPECTED AND RESULTS:

1. Four (4) Circumferential Welds:

   100 percent of these welds was inspected. A four inch (4") crack was found near the toe on the most Eastern head circumferential weld near the bottom of the vessel. Internal undercut was also observed (80% around). No action was taken.

2. Three (3) Longitudinal Welds:

   100 percent of these welds was inspected. Some cracked blisters were observed at the H.A.Z. areas of the most western longitudinal welds. No action was taken.

3. Baffle Plate:

   100 percent was inspected. A 2" longitudinal crack was found on the fillet weld cap; no action was taken.

4. Demister Ring Support Fillet Welds:

   100 percent of these welds were inspected. They were found to be acceptable.

5. Nozzles:

   100 percent of the following welds were inspected:

   18" Manway Acceptable

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IDENTIFICATION: PV-17.05; A-82506

EQUIPMENT DESCRIPTION: No. 1 Train, Sour Glycol Separator

TYPE OF INSPECTION: Internal Wet Fluorescent Magnetic Particle
Ultrasonic Flaw Detection

AREAS INSPECTED AND RESULTS:

N1 - 6" -Circumferential linear indications were observed at the weld fusion line.
-The average length was 0.250" and the longest was 1.250".
-No further action was taken.

NOTE: All other nozzles tested were found acceptable.

6. Special Note:

- Extensive blistering was observed inside the vessel between the West head circumferential weld to the manway location. As viewing the vessel from the West head, clock position of this blistering was 10 o'clock to 2 o'clock (top of vessel). The average size of blisters was 0.200" in diameter.
- Ultrasonic testing was carried out with the following observations:
- Attenuation loss (signal loss) in conjunction with indications ranging in depths, from O.D. surface, between 0.100" to 0.080" (average between 0.500" to 0.750").
- One (1) large blister was tested from inside the vessel and found to be 0.320" deep from the I.D. surface. This blister was approximately 3.0" diameter.

NO. 1 SOUR GLYCOL SEPARATOR

SOUTH HEAD	- Crater or CO2 type pitting circumferentially around the head in the rolled area 8 - 10" from the circ weld. (.055" deepest)
SHELL SOUTH END	- Minor pitting at 6 o'clock .010" far end. - Extensive blistering between the south head circ. weld and manway. The blisters are all between the 9 o'clock and 3 o'clock position. They average 2 - 3" in diameter. - One blister had blown out about 1/2 way between the manway and the south head circ weld.
DEMISTER RING	- The ring was skip welded on south side. Extensive cracking on the ring. - Extensive pitting on the south side of the demister ring.
MANWAY AREA	- Blisters located on south side of manway and directly above the manway at 12 o'clock.
NORTH SHELL	- Isolated pitting below the fluid level 1/4" diameter by .020" deep. - General pitting above the fluid level .040" - .060" deep. - Blisters at 12 o'clock. Near nozzle.

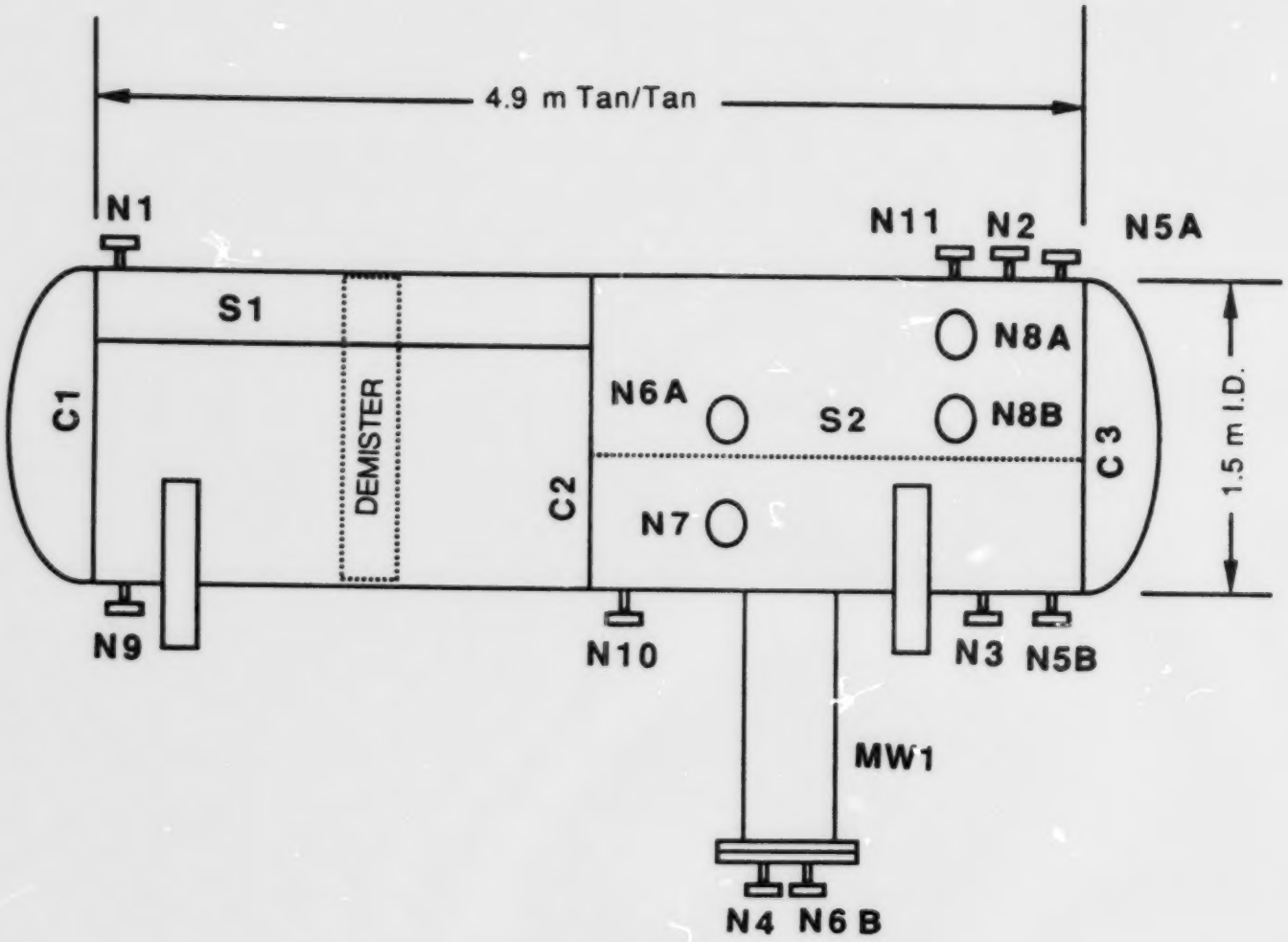

Figure 2 **No. 2 Train, Sour Glycol Separator**

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MATERIALS ENGINEERING AND TESTING

1989 SHUTDOWN INSPECTION REPORT

SOUTH STURGEON LAKE GAS PLANT

Date: April 1990
Pages: 1 of 3
No. of Drawings: 1

IDENTIFICATION: V-20-108

EQUIPMENT DESCRIPTION: No. 2 Train, Sour Glycol Separator

TYPE OF INSPECTION: Internal Wet Fluorescent Magnetic Particle
Ultrasonic Flaw Detection (Internal and External)

AREAS INSPECTED AND RESULTS:

1. East Circumferential Weld:

   100 percent of this weld was inspected. Two (2) 1/4" long cracks were found on the toe of the weld (head side).

2. Middle Circumferential Weld:

   100 percent of this weld was inspected. A 1/8" long toe crack was noted on the East side toe. A "sliver-like" indication was noted on the East side of the weld near the H.A.Z. (approximately 1.5" long, total).

3. West Circumferential Weld:

   100 percent of this weld was inspected. This was found to be acceptable.

4. East Longitudinal Weld:

   100 percent of this weld was inspected. Four (4) linear indications were observed near the parent material of the weld. The longest was 1.0" near the gouged area. A v-shaped linear indication (1.0" long, total) was noted at the weld toe.

5. West Longitudinal Weld:

   100 percent of this weld was inspected. A 1/8" long transverse crack was noted in the H.A.Z. A "sliver-like" indication was also observed in the H.A.Z. (approximately 2" total).

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SOUTH STURGEON LAKE GAS PLANT

Date: April 1990
Pages: 2 of 3
No. of Drawings: 1

IDENTIFICATION: V-20-108

EQUIPMENT DESCRIPTION: No. 2 Train, Sour Glycol Separator

TYPE OF INSPECTION: Internal Wet Fluorescent Magnetic Particle
Ultrasonic Flaw Detection (Internal and External)

AREAS INSPECTED AND RESULTS:

6. 6" Inlet Nozzle No. N1 Deflector Plate Fillet Welds:

   100 percent of this weld was inspected. Five (5) locations of toe cracking (shell side) were noted having lengths of 1/4" to 1 1/2".

7. Baffle Plate Fillet Welds:

   100 percent of this weld was inspected. Two (2) cracks were observed at the weld area; one 3/4" long on the South fillet cap (longitudinal) and one 1/8" long in the H.A.Z. of the North fillet (transverse).

8. 18" Manway:

   100 percent was inspected. Ten areas of nonfusion and/or cracking on the weld toe (shell side) were noted, ranging in lengths from 1/8" to 4.0".

9. East Demister Support Fillet Welds:

   100 percent of these welds were inspected. Seven (7) areas of toe cracking and undercut were noted. Two (2) of the areas (near the top of the vessel) were evaluated by ultrasonic inspection from the O.D. surface and accessed to be 0.080" and 0.330", respectively.

10. West Demister Support Fillet Welds:

    100 percent of these welds were inspected. An area 6" long was observed with toe cracking (shell side), associated with weld undercut.

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MATERIALS ENGINEERING AND TESTING

1989 SHUTDOWN INSPECTION REPORT

SOUTH STURGEON LAKE GAS PLANT

Date: April 1990
Pages: 3 of 3
No. of Drawings: 1

IDENTIFICATION: V-20-108

EQUIPMENT DESCRIPTION: No. 2 Train, Sour Glycol Separator

TYPE OF INSPECTION: Internal Wet Fluorescent Magnetic Particle
Ultrasonic Flaw Detection (Internal and External)

AREAS INSPECTED AND RESULTS:

11. Shell:

I.D. blistering was observed from East to West heads between the 9 o'clock and 3 o'clock positions (top shell), as viewed from the East. The concentration was in the area of the 6" gas-out nozzle No. N1. The depth was evaluated to be between 0.090" to 0.650" (from the I.D. surface). It was also evaluated from the O.D. surface and indications ranged between 0.550" to 0.750" deep (from O.D.).

NOTE: The O.D. ultrasonic scanning included the top section of the vessel about 4' by 10' in size.

The remaining blistering was randomly evaluated to be between 0.100" to 0.200" in depth from the I.D. surface.

SPECIAL
*NOTE: All indications and observations noted were not removed or retested after initial inspection.

Amoco Canada Petroleum Company Ltd.
Sturgeon Lake South Gas Plant

May , 1990

Re: Field report of P-Scan inspection

PV-17.05 Sour Glycol Separator demister ring fillet welds (east & west)

The inspection of the two welds shows cracking around most of the weld circumference on both demister rings. Cracks are on average .125" in depth with the deepest indication on the west ring at .240 mils (single indication). See print out for length indications. Pitting was also detected on the upper shell at a maximum depth of 270 mils. Small laminations were also detected along the weld zone.

PV-20.105 No.2, 2nd. Stage Discharge Scrubber

The inspection shows numerous small near surface horizontal lamination/inclusions indications (printout PV20105A, B, & C). Indications become almost non existent at 1.5 m above the bottom weld (PV20105c). Indications at .5 m from the weld start to show the laminar defects throughout the lower 2/3 rd. of the thickness (from the OD).

PV-17.22 No.2 Sweet Gas Scrubber

The inspection showed small laminar defects along the head to shell weld at near the ID surface. These indications are much less than the code requirements and do not present any problem.

A final and more detailed report will be issued.

Should have any question in the meantime, please contact myself on my mobil (1-554-5286)

Yours truly,

Ultratest NDT Services Inc.

Klaus Kuhn

#2 Sour Glycol SEPARATOR.

P-Scan inspection locations
PV-17.06 Sour Glycol Contactor

Amoco Canada Petroleum Co. Ltd.
Sturgeon Lake South Gas Plant
DE- 2-90-22VS

ULTRATEST

By: KMK Date: 8/90 Dwg: 1